

An update on the strangeness production measurements and H_0 di-baryon search as performed by the AGS experiment 896

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Abstract

E896 was designed to search for the predicted short-lived six-quark H_0 di-baryon. The goal is to enhance the existing knowledge by extending the search into regions of shorter lifetimes (approximately half that of the lambda) and via exploring a new creation channel, that of the coalescence of two lambdas. Two main tracking chambers are used, a distributed drift chamber positioned to measure low- p_t and high-rapidity neutral particle decay products and a silicon drift detector array which measures particle production at mid-rapidity. Both detectors are also investigating lambda polarization, over their respective coverages, for Au–Au collisions at 11.3 GeV/nucleon. The current status of the H_0 di-baryon search and preliminary results of the strange particle production and polarization measurements will be presented.

(Some figures in this article are in colour only in the electronic version; see www.iop.org)

1. Introduction

The H_0 di-baryon (a six-quark state of uuddss) was first predicted by Jaffe [1] over 20 years ago. To date no conclusive proof has been found for the existence of this metastable strangelet, although many experiments have been performed, e.g. E810 [2], E888 [3], E836 [4]. (See [5] for an overview summary of the search for the H_0 .)

Simple coalescence arguments [6] indicate that heavy-ion collisions should provide an ideal environment for the creation of di- Λ s, due to the large production of Λ s. If the H_0 is more deeply bound than a coalescing $\Lambda\Lambda$ pair they may spontaneously decay into an H_0 . This process allows for the creation of the strangelet without the need for quark–gluon plasma formation.

E896 was optimized to search for the H_0 using two complementary tracking detectors, a distributed drift chamber (DDC) and a silicon drift detector array (SDDA). The DDC has a large sensitivity to detect the H_0 decay modes $H_0 \rightarrow \Sigma^- p \rightarrow pn\pi^-$ and $H_0 \rightarrow \Lambda p\pi^-$ over a wide range of lifetimes, while the SDDA is ideally positioned for detecting the H_0 via the latter decay mode, with a $c\tau \sim 4$ cm, at the low end of the DDC's sensitivity range.

The SDDA also has a good acceptance for measuring the Λ around mid-rapidity via its decay products. The DDC identifies Λ , $\bar{\Lambda}$ and K_s^0 at high rapidity and low p_t . The differing acceptances of the SDDA and DDC combined with the symmetry of the collision means that E896 measures the production of Λ s over virtually the whole rapidity region. These results complement the hyperon measurements already reported by previous SPS and AGS experiments [8].

Both tracking detectors, again in a complementary fashion, have also made preliminary Λ polarization measurements. Λ polarization was first observed in 1976 in proton-induced reactions [9]. It was shown that fragmentation region Λ s are polarized such that their spin is pointing normal to the production plane as defined by the beam and the Λ line of flight. This unexpected result (it had previously been believed that spin effects would be negligible in high-energy hadronic reactions) has since been confirmed by many experiments. The main p–p collision Λ polarization results are that (a) the Λ s are produced with negative polarization, (b) for $p_t < 1$ GeV c^{-1} the polarization increases linearly with p_t and x_f , although the x_f dependence is somewhat steeper, and (c) for $p_t > 1$ GeV c^{-1} the polarization saturates as a function of p_t but continues to increase with x_f . Many attempts have since been made to interpret these results with the main idea being that the s quark is responsible for carrying the polarization of the Λ . The negative sign of the polarization is attributed to the fact that it is more probable for the ud di-quark to combine with a spin down s quark than with a spin up. Reference [10] provides a theoretical review of this subject. The interest in studying polarization in heavy-ion collisions is to search for a possible change in the polarization systematics due to the unprecedented high temperatures and densities created in the fireball.

2. The AGS experiment 896

Experiment 896 was a fixed-target experiment carried out at the Brookhaven AGS using Au–Au collisions at 11.3 GeV/nucleon. The design of E896 can be seen schematically in figure 1. The SDDA, positioned in the 6.2 T sweeper magnet approximately 10 cm downstream of the target, consisted of 15 planes of silicon drift detectors [11]. Each plane of the SDDA was formed by a $6.3 \text{ cm} \times 6.3 \text{ cm} \times 300 \mu\text{m}$ n-type silicon wafer. The SDDA was a prototype of the technology to be used by the STAR experiment [12] in the silicon vertex tracker (SVT). The 144-plane DDC had ~ 8000 channels and an active volume of $120 \times 67.5 \times 20 \text{ cm}^3$. It was located 1.3 m downstream of the target in a 1.7 T analysing magnet.

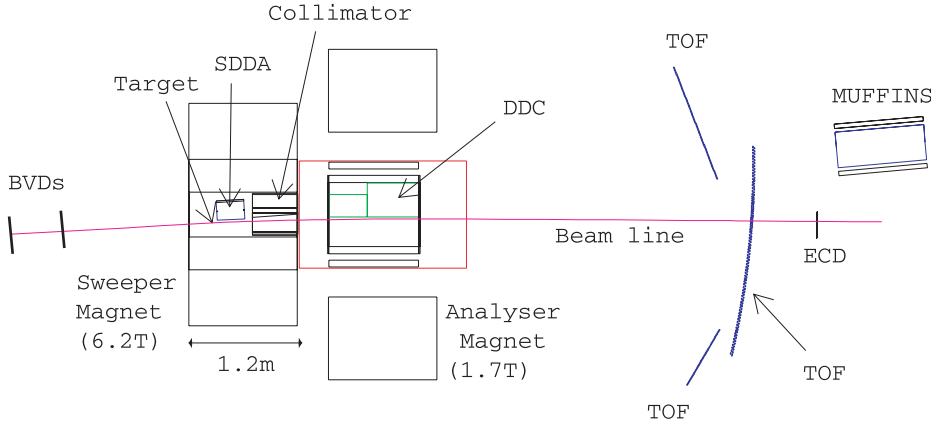


Figure 1. The experimental set-up.

Although the H_0 can be identified unambiguously using a constrained fit to the unique topology characteristics of the $H_0 \rightarrow \Sigma^- p$ decay, redundant particle identification is provided by using the multi-functional neutron spectrometer (MUFFINS) [13] to detect the neutron from the subsequent Σ^- decay and the time-of-flight (TOF) walls to aid the definition of the charged tracks reconstructed in the DDC.

Two beam vertexing detectors (BVDs) were used for locating the primary vertex position and beam angle, while a forward multiplicity array determined the centrality of the collision for triggering.

3. Results

During the April 1998 run 80×10^6 central events were recorded by the DDC and 680 000 central events by the SDDA. Central events are defined as the top 5% of the measured signal in the forward multiplicity array. Since silicon drift detectors take longer to read out than the gas chambers used, the SDDA was operated using a separate 1 Hz data acquisition system.

On average there are less than 10 tracks in the DDC per event (figure 6 shows a typical central event recorded by the DDC). This clean environment, created by the high sweeper field and collimator, means that the track reconstruction efficiency in the DDC is high. Neutral decays occurring within the DDC can be cleanly reconstructed with very little background. This is to be compared with the higher track density observed in the SDDA of ~ 60 particles per event [14]. The acceptance for the Λ s in the SDDA and DDC is shown in figure 2 as a function of p_t and rapidity.

3.1. The SDDA Λ results

Presented here are preliminary results for Λ polarization as measured by the SDDA. The whole SDDA data set was used in this analysis yielding ~ 5700 Λ s with a mass resolution of 5 MeV. Figure 3 shows the Λ polarization as a function of x_f for various p_t bins. For $x_f < 0.25$, $\langle p_t \rangle = 0.8 \text{ GeV } c^{-1}$, for $0.25 < x_f < 0.4$, $\langle p_t \rangle = 1.2 \text{ GeV } c^{-1}$ and for $x_f > 0.4$, $\langle p_t \rangle = 1.7 \text{ GeV } c^{-1}$. These results show no significant deviations from previously reported p-p polarization measurements both in sign and size.

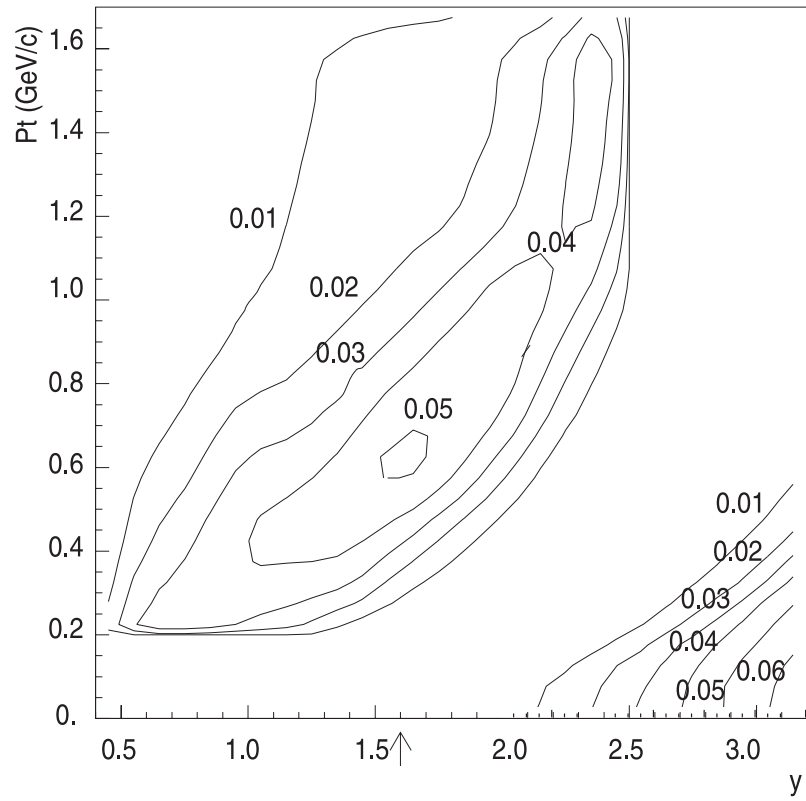


Figure 2. Λ acceptance in the SDDA and DDC as a function of p_t and rapidity. The contours are labelled with the fractional acceptance and the arrow indicates mid-rapidity.

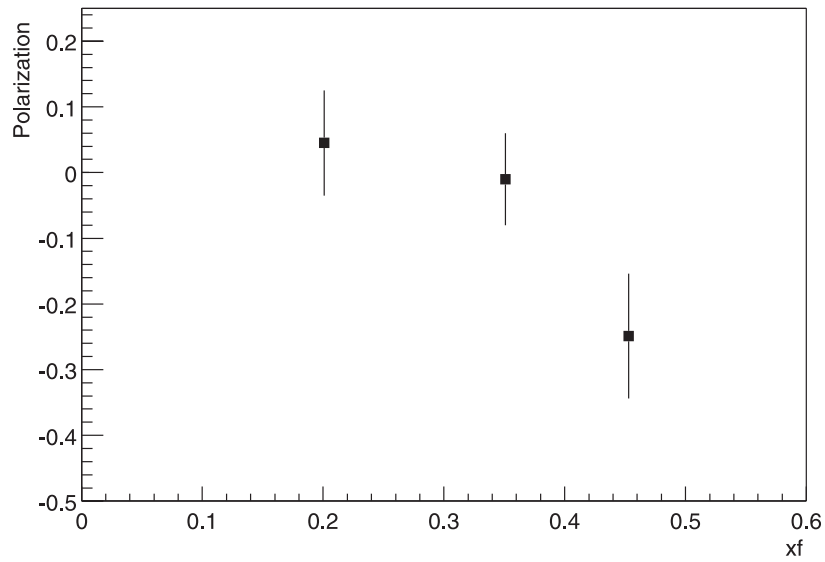


Figure 3. Λ polarization in the SDDA.

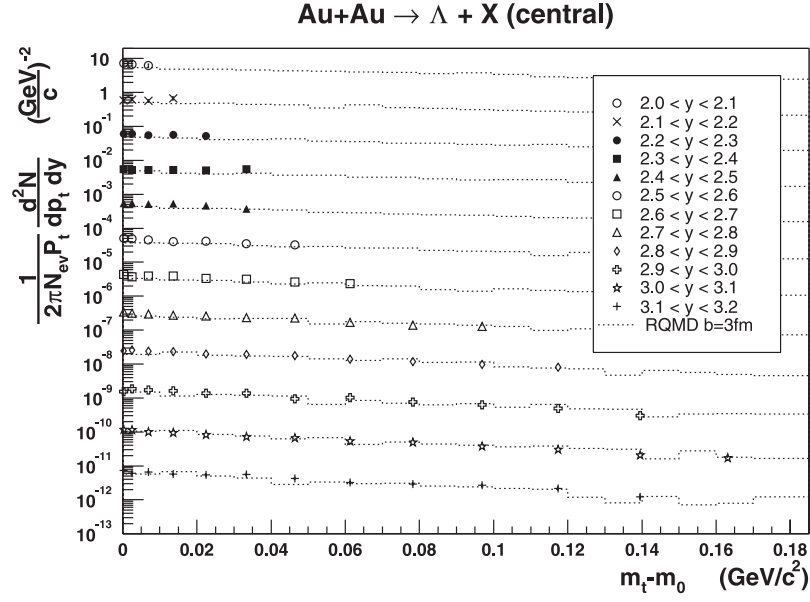


Figure 4. The DDC Λ m_t spectra, successive bins in rapidity are scaled by powers of ten. The dotted lines are predictions from RQMD V2.4.

3.2. The DDC Λ results

From the DDC $\sim 72\,000$ Λ s have been measured with the requirement that the reconstructed v_0 occurs within the fiducial volume of the DDC. The mass resolution of these Λ s is 4 MeV.

Figure 4 shows the m_t spectra for Λ reconstructed within the DDC volume. The m_t range is insufficient to perform fits to the slopes. However, the data have been compared with experiment 891 [15] and are consistent over the E896 phase space. The data in figure 4 are also compared with RQMD V2.4 [16] with the impact parameter range $0 < b < 3$ fm. This range is comparable to the E896 estimated centrality. It can be seen that the RQMD model reproduces the shape of the measured distributions over the region covered, however, it was necessary to scale the RQMD results up by a factor of 1.2 to obtain good agreement with the absolute yields in the present data.

The preliminary measured Λ polarization for $x_f \geq 0.7$ is shown in figure 5 as a function of p_t . These results are again consistent with p-p(Be) measurements over similar kinematic ranges.

3.3. The DDC H_0 predictions

The H_0 reconstruction process is demonstrated in figure 6 where a decaying H_0 has been embedded into a real DDC event. First the algorithm identifies a stiff positive particle, next a negative track is located with which the stiff positive track appears to form a secondary vertex within the active volume of the DDC. If successful, a search is then performed for a kink in the negative track. If all three steps are successful the event is flagged as containing a possible H_0 candidate and thus requiring further investigation. The H_0 embedded in figure 6 was correctly identified by this technique.

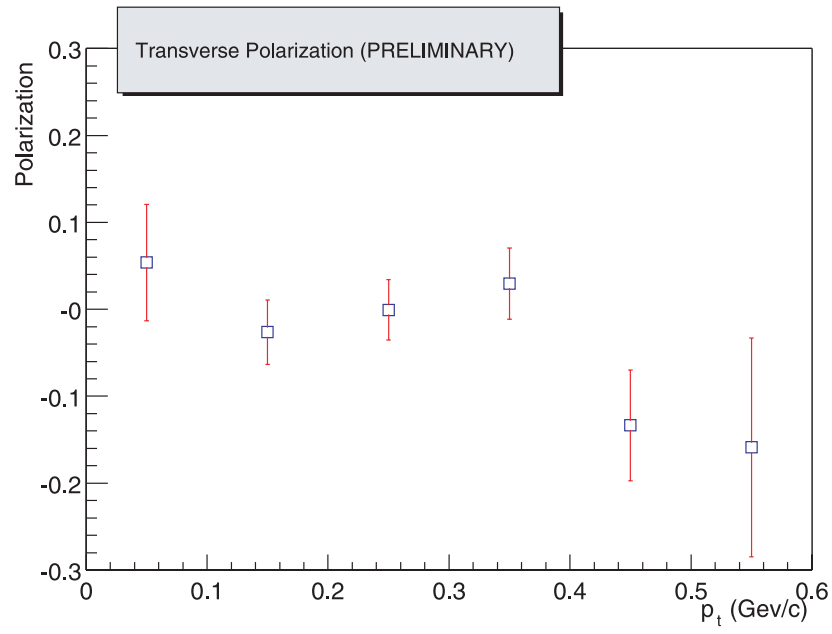


Figure 5. The DDC Λ polarization as a function of p_t .

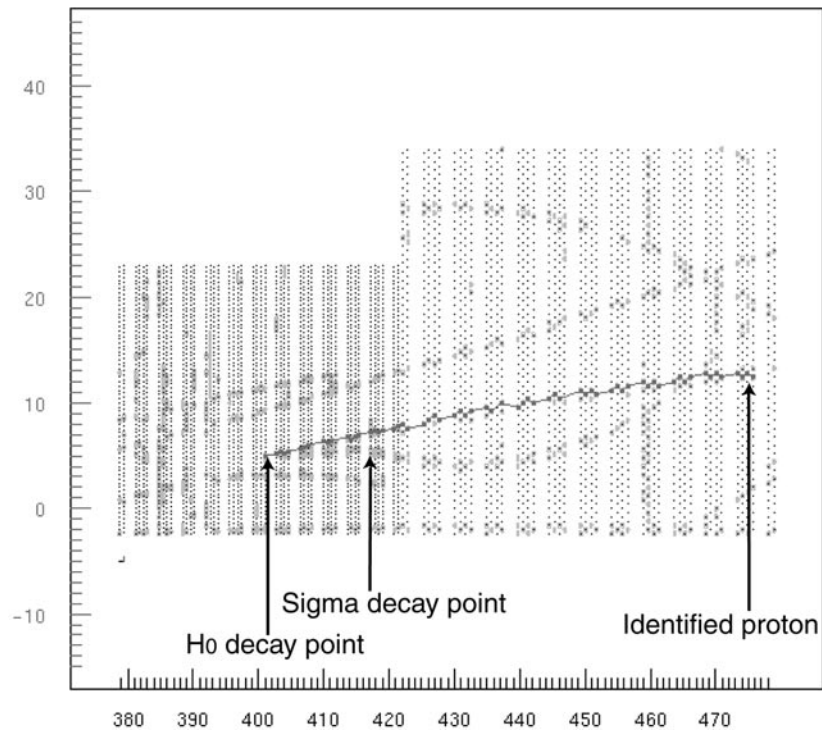


Figure 6. An embedded H_0 in a real DDC event and correctly reconstructed via the current software.

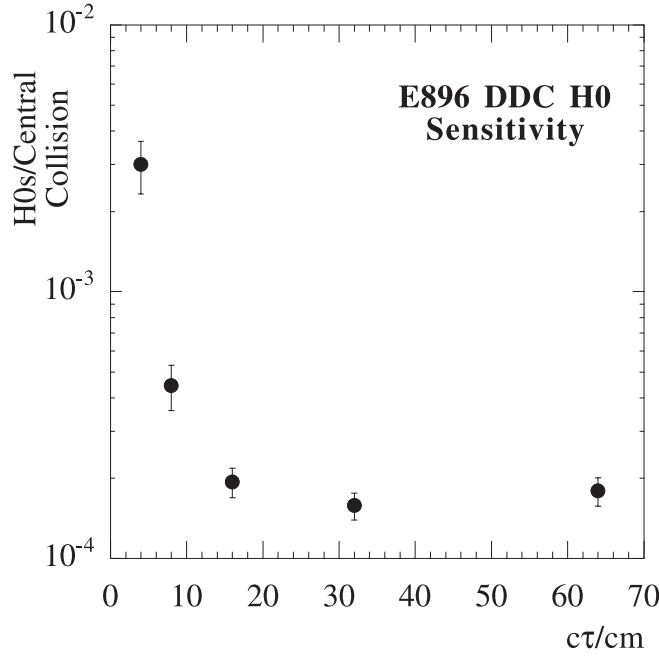


Figure 7. The DDC sensitivity to the H_0 as a function of lifetime.

From calculations of the acceptance and efficiency for H_0 reconstruction using embedding of simulated H_0 s into real data we can estimate our sensitivity for identifying H_0 s. The sensitivity is strongly dependent on the lifetime of the H_0 and is defined by

$$\text{sensitivity} = \frac{\text{no of } H_0}{\text{no of events} \times \text{acc} \times \text{eff} \times \text{BR}} \quad (1)$$

where the acceptance (acc) and efficiency (eff) were calculated from simulations, 10^8 events were assumed and 2 H_0 s, with a branching ratio (BR) of $\frac{1}{3}$ [17] were required to be identified to constitute a ‘discovery’. The calculated sensitivity as a function of the H_0 lifetime is shown in figure 7.

4. Conclusion

The DDC recorded 80×10^6 central events and the SDDA 680 000 central events. Based on the coalescence model, which suggests the possibility of 0.1 H_0 /central collision and a $c\tau = 4$ cm, and the acceptance and reconstruction efficiency of the detector, the DDC may reconstruct as many as 200 H_0 s. The statistics taken by the detector should allow a definite statement to be made about the existence of the H_0 di-baryon.

The SDDA has been shown to be a mature technology which is able to track efficiently in a high-multiplicity regime and high magnetic field. Λ s have been identified via their v_0 topology with a mass resolution of 5 MeV. The DDC has identified Λ s with a mass resolution of 4 MeV. Comparisons of the DDC p_t spectra for various rapidity slices with RQMD and E891 results have shown good agreement.

First measurements of the polarization of the Λ hyperon in relativistic heavy-ion collisions have been made in both the SDDA and DDC tracking detectors. These results indicate that

the Λ is polarized at high p_t and x_f in Au–Au collisions, but that this polarization is lost for those Λ emitted from the central fireball region. The sign and size of the polarization is in agreement with the p–p data.

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